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Topographical and Climatic Factors Influencing the Distribtion of *D. andersoni* Across Western Montana

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Abstract

The Rocky Mountain wood tick, *Dermacentor andersoni*, has a high prevalence in the Western United States and is a known vector for Colorado Tick Fever, Rocky Mountain spotted fever and other infectious diseases. Though prevalent, their distribution is still poorly understood. The goal of this study was to examine topographical and climatic factors influencing *D. andersoni's* distribution over Western Montana. This study consists of data collected from 145 total sites from 2013 to 2016. At each site, ticks were captured using a drag sampling technique and were categorized in terms of abundance. Various climatic and topographical data were obtained on-site and through the National Elevation Dataset, NASA Earth Observation and the PRISM Climate Group. The study found that May Normalized Difference Vegetative Index (NDVI), average spring precipitation and average summer temperatures were significant in distinguishing between sites of different *D. andersoni* abundance.

Introduction

The Rocky Mountain Wood Tick, *Dermacentor andersoni*, is the most significant North American tick in regards to disease transmission (Mail, 1942). It is the main vector for Colorado Tick Fever, Rocky Mountain spotted fever, tularemia and tick paralysis along the Sierra Nevada and Cascade Mountain ranges in North America (Yoder *et al.*, 2003). James *et al.* (2006) found that Montana locations represented nearly a quarter of *D. andersoni* populations sampled between 1921 and 1941. These data were compiled from a total of 267 counties in 14 different states. However, spatial patterns of risk for human exposure to disease pathogens are still poorly understood (Eisen *et. al*, 2007).

D. andersoni is an ixodid tick that requires a blood meal from a vertebrate host in order to molt through its three typical stages of life: larval, nymphal and adult (Fielden & Lighton, 1996). However, the nonparasitic periods between the different stages account for more than 98% of the tick's total life cycle (Fielden & Lighton, 1996). Thus, it is not surprising that ticks are able to survive longer than any other arthropods without access to food or free water (Fielden & Lighton, 1996). This is significant because the characteristics and adaptations ticks use to thrive can correlate with their environment. *D. andersoni* are classified as xerophilic and have low rates of net transpiration thus giving them the noteworthy ability to function in dry environments and the inability to tolerate life in moisture rich environments (Yoder *et al.*, 2003). In fact, all stages of *D. andersoni* rely on water vapor as the primary source of water (Yoder *et al.*, 2003). Additionally, relative soil humidity must be adequate to prevent dessication of eggs thus making vegetative cover and altitude equally important in identifying areas inhabited by ticks (Carey *et al.*, 2003). Although Eisen *et al.* (2007) identified open grasses and big sagebrush to be general indicators of areas for elevated risk of exposure to host-seeking *D. andersoni*, no significant vegetative data have been collected for Montana.

Eisen *et al.* (2007) found that climatic factors are most significant when predicting tick presence in a given area. Densities of *D. andersoni* were greatest when maximum daily temperatures were between 16-19 °C and the relative humidity was greater than 20% in Larimer Country, CO. Due to *D. andersoni's* high dehydration tolerance and xerophilic characteristics, its typical habitats and peak activity occur in areas that are hot and dry (Yoder *et al.*, 2003). A corresponding decrease in tick numbers were seen in areas where maximum temperatures exceeded 20°C and daily relative humidity fell below 20% (Eisen *et al.*, 2007). In addition to these climatic variables, topographical features such as elevation play a role in determining the presence of ticks and Eisen *et al.* (2007) found that in the analysis of an elevation gradient ranging from 1,700 to 2,500 m peak abundance of ticks occurred at elevations between 2200 and 2400 m while decreasing densities were seen at much lower and higher elevations.

D. andersoni are active for a period ranging from 84 to 104 days in the months of March to late June (Eisen, 2007) and therefore its distribution and activity across North America is a growing health concern to those camping and participating in other recreational activities (Yoder *et al.*, 2003). Due to growing population centers surrounding the Rocky Mountain region, the level of recreational activities on tick habitats is expected to increase (Eisen *et al.*, 2007). This in turn might correlate with an increase in human contact with *D. andersoni* and the transmission of its associated diseases (Eisen *et al.*, 2007). Montana, being an outdoor oriented state, may be subject to this rise in human exposure.

Models assessing tick distribution in Montana have not yet been completed. Furthermore, determining suitable habitats for *D. andersoni* is a multivariate problem that involves correlations and interactions between environmental factors. These environmental factors include humidity, temperature, precipitation, vegetation and elevation to name a few. For this reason, it is difficult to find corroboration across the literature for the environmental factors that predict tick presence and abundance (Schaalje & Wilkinson, 1985). Thus, there is a need for a model that integrates topographical and climatic factors listed in the literature into one predictive model. Such a model may provide insight into the distribution of *D. andersoni* in Montana and by extension, the disease pathogens it carries.

The goal of the present study is to understand the environmental factors that determine tick presence that will allow future studies to build an effective distribution model. Of environmental factors under study – vegetation, humidity, precipitation, elevation and temperature – I hypothesize that temperature and vegetative factors will be most significant in determining tick presence after discriminant analysis.

Material and Methods

I. Collection of sampling data

Samples were collected from early May to late June (2016) from 145 sites consisting of both historic and new sites across Western Montana (Figure 1).

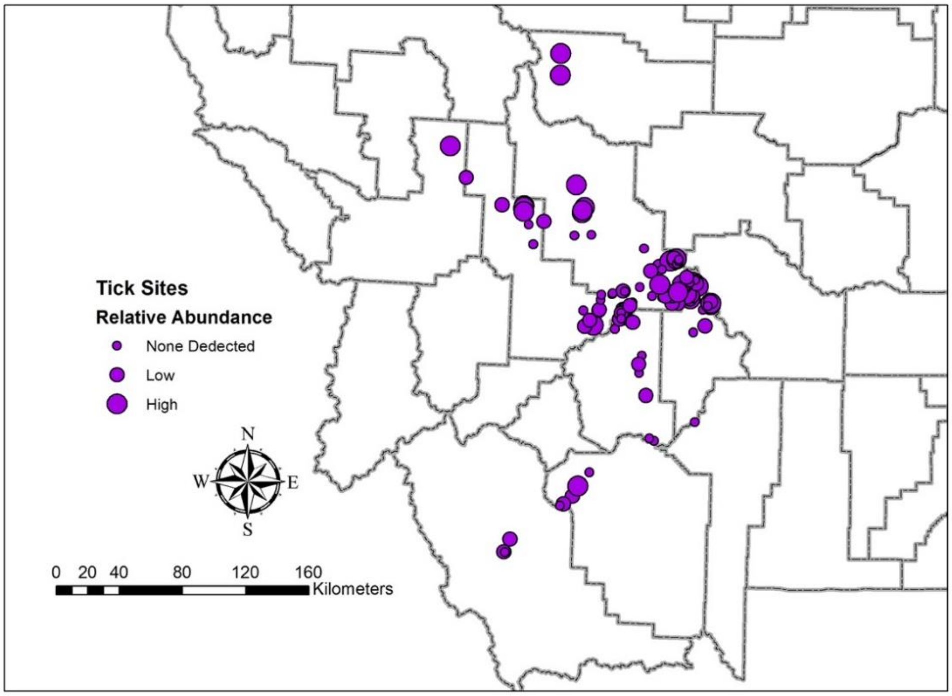

Figure 1. Map of Western Montana showing distribution of sampling sites.

Ticks were collected using a drag sampling technique to mimic the movement of a human or host to yield a realistic measure of human exposure to *D. andersoni* (Eisen, 2007). The flagging apparatus was composed of PVC piping in the shape of a "T" with a flannel cloth attached to its horizontal end. For each site, there was a total of one hour of sampling time. The number of ticks found at each site was recorded. These sites were then categorized into three groups depending on the amount of ticks found: None – indicating that no ticks were found at the site, Low – indicating that 1-5 ticks were found at the site and High – indicating that six or more ticks were found at the site. Of the 145 sites sampled, 70 were categorized as none, 51 as low and 24 as high.

For each site, GPS coordinates were taken using North American Datum of 1983 (NAD-83 datum) and environmental climate data were measured using a Kestrel 3000 pocket weather meter which obtained air temperature, relative humidity and wind speed. Other climatic data for analysis were gathered from the PRISM (Parameter-elevation Relationships on Independent

Slopes Model) Climate Group. Climatic data from the PRISM Climate Group included average summer, winter and spring temperatures in addition to average spring precipitation. Data were collected with respect to the 30-Year Normals provided by the PRISM Climate Group. Following each decade, average values for these varying climatic factors are computed and averaged for the previous 30 years (PRISM, 2016). The current set of data used in this analysis include averages from 1981-2010 (PRISM, 2016). Elevation data were acquired from the National Elevation Dataset (NED), a primary product of the United States Geological Survey (USGS; NASA, 2016). Quantitative vegetative data were collected using the Normalized Difference Vegetation Index provided by NASA Earth Observations (NEO, 2016). The index is reflective of areas that are covered by green vegetation, 0.4-0.9, to areas that show no or little vegetation, 0-0.4 (NEO, 2016). Scientists are able to detect the reflection of near-infrared light by chlorophyll producing vegetation to ultimately produce the resulting value called the NDVI (NEO, 2016). The NDVI maps were generated using data gathered by the Moderate Resolution Spectroradiometer (MODIS) aboard NASA's Terra satellite (NEO, 2016). Elevation, May NDVI, spring precipitation and summer temperatures layered over Western Montana are shown in Figure 2.

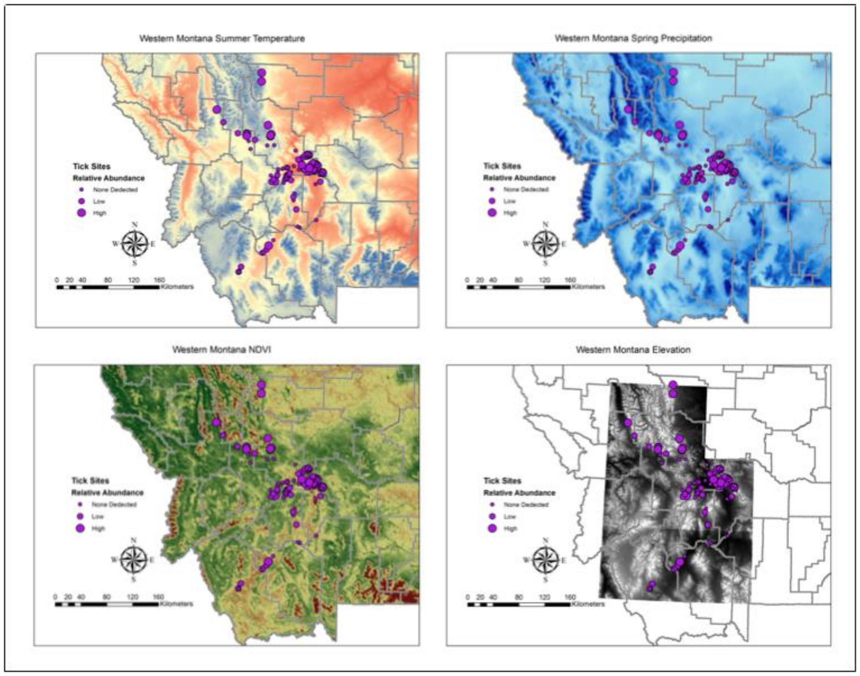

Figure 2. Sample sites across Western Montana with respective data layers.

II. Statistical Analysis

Given non-normal distribution of the data, a Kruskal-Wallis test was implemented to study the ecological factors determining tick distribution. The Kruskal-Wallis test is a non-parametric method that does not assume normal distribution and performs a One-way ANOVA based on ranks. This analysis was used to assess which ecological and climatic factors are most significantly associated with tick density.

Results:

Of the seven single factor ANOVA tests completed on the raw data, two independent variables suggested statistical significance. Significant positive correlation was found between *D. andersoni* abundance and average spring precipitation (p=.024). Significant negative correlation was found when examining average summer temperatures (p=.031; Table 1). Two other independent variables, May NDVI and average spring temperature, were close to reaching statistical significance (Table 1).

Table 1. Regression analysis of environmental factors versus tick abundance.

Dependent Variable	Independent Variable	P-Value
D.andersoni abundance	Humidity	0.111
D.andersoni abundance	May NDVI	0.081
D.andersoni abundance	Elevation	0.226
D.andersoni abundance	Average Spring Precipitation	0.024
D.andersoni abundance	Average Spring Temperature	0.096
D.andersoni abundance	Average Summer Temperature	0.030
D.andersoni abundance	Average Winter Temperature	0.105

Upon further analysis, a Kruskal-Wallis test confirmed that May NDVI has some significant positive correlation with tick numbers in addition to spring precipitation and summer temperatures. There was significant difference (p=0.021) in spring precipitation between tick populations of high abundance and low abundance. However, no significance was obtained in differentiating high abundance to none, and low abundance to none with respect to spring precipitation (Figure 3). Summer temperatures showed a significant difference (p=0.024) between tick populations of high and low abundance and additionally followed the same trend as spring precipitation (Figure 4). There was a significant difference (p=0.024) in May NDVI for populations of ticks with high abundance versus no ticks and for high abundance vs. low abundance. There was no significant difference in May NDVI for populations of low abundance versus no ticks (Figure 4). May NDVI, average summer temperatures and average spring precipitation values are shown below (Table 2). Kruskal-Wallis one-way ANOVA test further validated the zero significance found for humidity, elevation, average spring temperature and average winter temperature with respect to tick abundance (Figure 6, 7, 8 and 9, respectively).

Table 2. Data values for significant factors based on Kruskal-Wallis one-way ANOVA analysis.

Factor	High	Low	None
May NDVI	0.536	0.486	0.482
Average Summer Temperature	14.97˚C	16.08˚C	15.68˚C
Average Spring Precipitation	49.53 in.	40.47 in.	45.19 in.

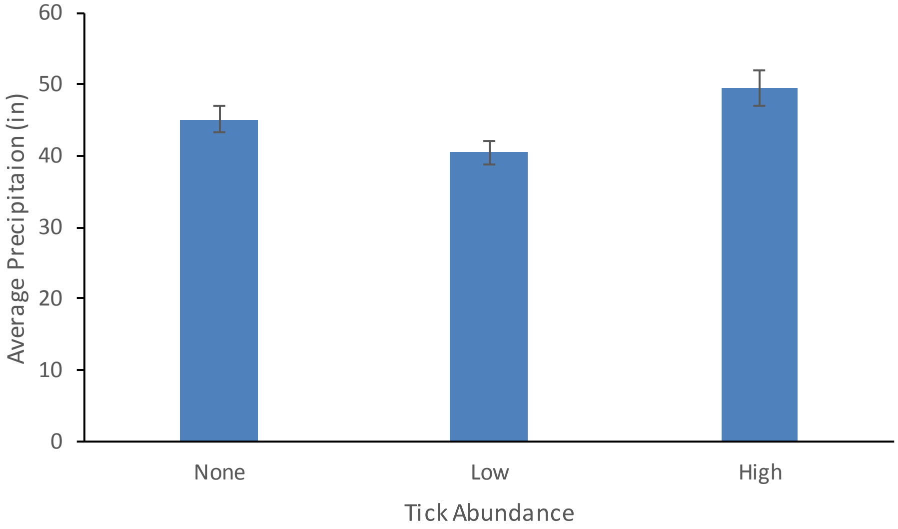

Figure 3. Average precipitation (in) for each category of tick abundance.

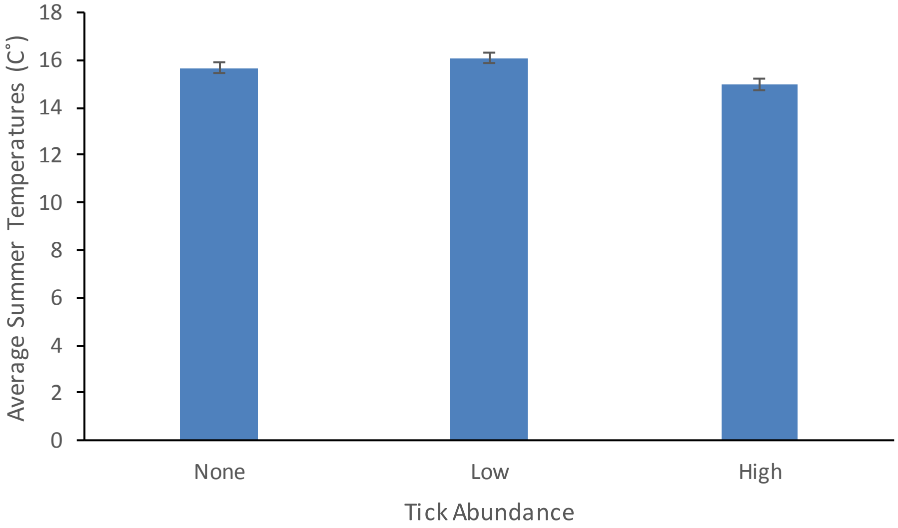

Figure 4. Average summer temperatures for each category of tick abundance.

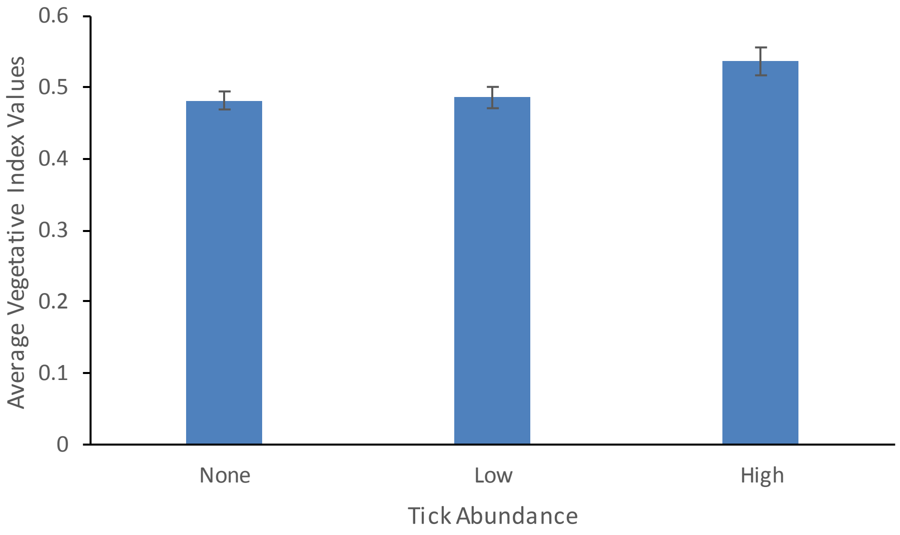

Figure 5. Average May vegetative index values for each category of tick abundance.

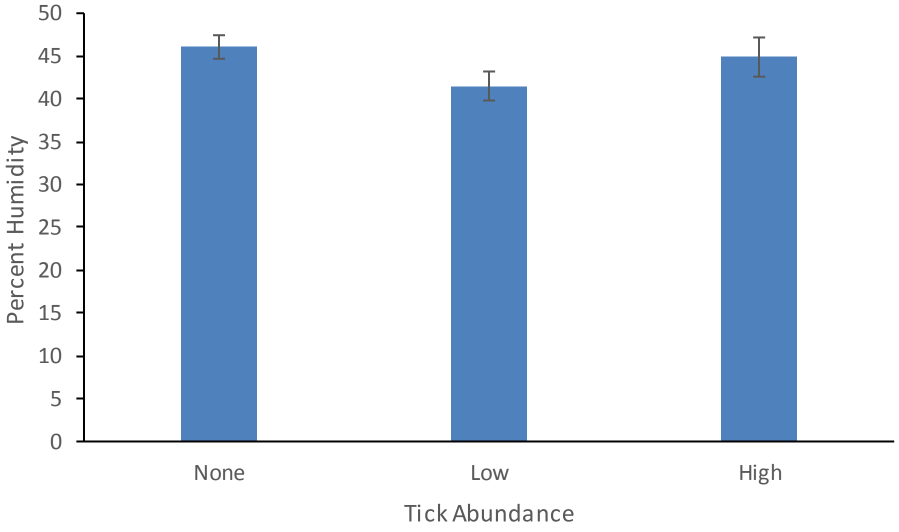

Figure 6. Average percent humidities for each category of tick abundance.

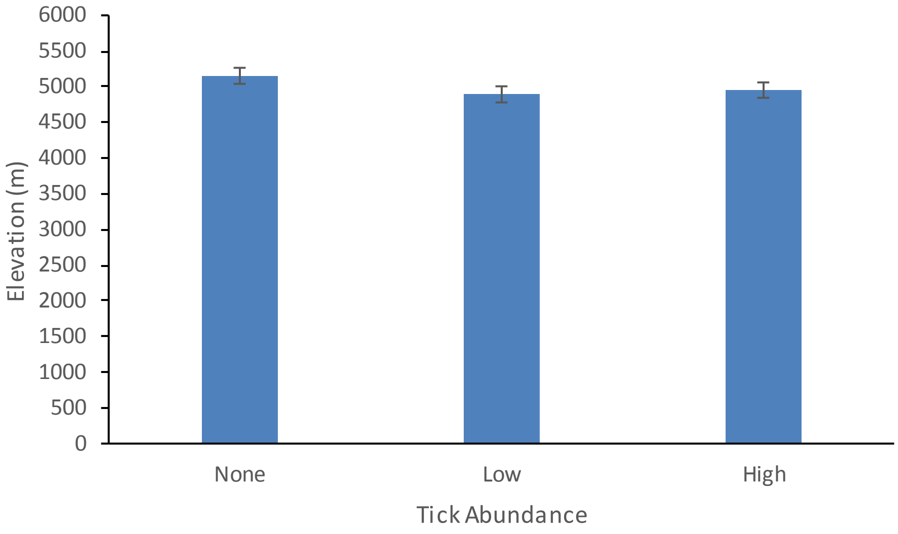

Figure 7. Average elevation for each category of tick abundance.

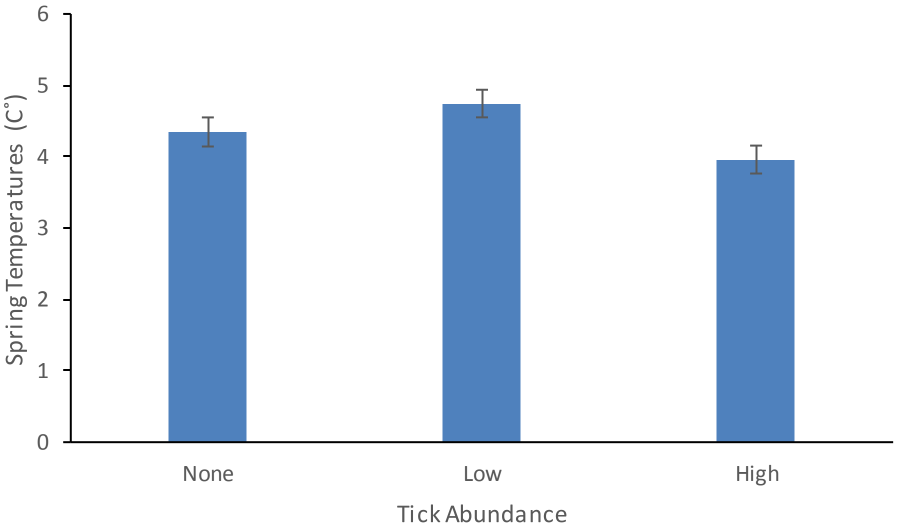

Figure 8. Average spring temperatures for each category of tick abundance.

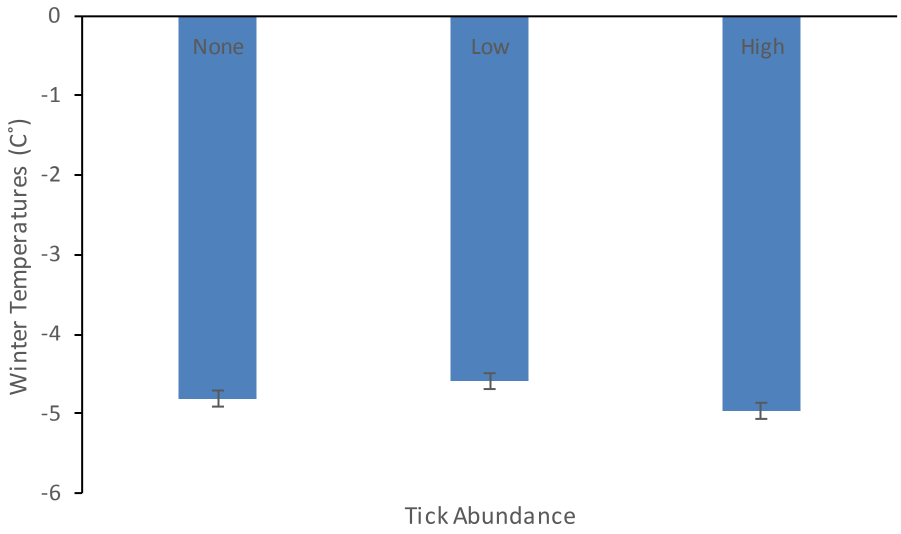

Figure 9. Average winter temperatures for each category of tick abundance.

Discussion:

The goal of this study was to identify factors contributing to the distribution of *D. andersoni* in Western Montana. It was hypothesized that vegetation and temperature would be the most significant factors influencing the distribution. Both of these environmental factors were significant in determining differences in tick abundance along with average spring precipitation values.

Eisen *et al.* (2007) found that densities of *D. andersoni* were greatest when maximum daily temperatures were between 16-19˚C from March to July in Larimer County, CO. The present study showed that there was no significant difference in tick abundance with respect to spring temperatures during March, April and May months. Additionally, there was significance between low abundance of ticks and high abundance of ticks with regards to average summer temperatures consisting of June, July and August months. These high abundance sites had significantly lower average temperatures than the low abundance sites – 14.97˚C and 16.08˚C, respectively. It is presumed that the differences in the Eisen *et al.* study and this study are due to other varying and contributing ecological differences between Colorado and Montana. However, there was no significant difference in average summer temperatures between sites with high abundance and sites with no abundance. This data suggests that some factor other than temperature is responsible for determining tick presence.

D. andersoni's xerophilic properties allow them to function most effectively in dry environments (Yoder et al., 2003). However, in the present study sample sites yielding high abundance of ticks had a higher average spring precipitation (125.81 cm) compared the lowest precipitation site (102.79 cm). Similar to average summer temperatures though, there was no difference in average spring precipitation between sites with high abundance and no abundance. Given the characteristics of *D. andersoni*, this result is puzzling. Previous studies suggest that a higher abundance of ticks would be found at sites with a lower average precipitation. However, the significance of May NDVI in determining their distribution may help explain this phenomenon.

Previous studies have shown that vegetation including open grasses and big sagebrush to be general indicators of areas with greater densities of ticks (Carey *et al.*, 2003). Though no significant vegetative data have been examined in Montana, the May NDVI showed the greatest significance in this study. Areas of high abundance were significantly different from both areas of low and no abundance in regards to NDVI values. This suggests that more vegetation results in a higher abundance of ticks. Presumably, higher average spring precipitation values will result in greater growth of vegetation and ultimately a higher May NDVI value.

Given the disparity in number between sites categorized as none, low and high, covariant analysis could not be performed and an effective model assessing tick distribution could not be generated. A greater number of sites consisting of low and high tick abundance are needed to further this goal. However, the information presented in this study is a good foundation for understanding the distribution of *D. andersoni* in Montana. Continuation of climatic and topographical data collection from a greater variety of sites across all of Montana is suggested for future study.

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